Reply Comments for "Progeny Test Report"

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Several companies including SkyTel have commented on the test report submitted to the FCC by Progeny. Progeny had submitted a test report along with the description of their Wide Area Positioning System (WAPS) to meet the FCC requirements. This Reply Paper provides an integrated view of the shortcomings of the Progeny report by consolidating the viewpoints expressed by SkyTel and other companies in their submissions to the FCC, as well as relevant comments on LTE intrinsic location technology and service.

Here are the key shortcomings of the Progeny report.

- Cooperative testing between the WAPS and existing Part 15 systems is not carried out.
- Inherent lack of co-channel interference (CCI) for most test devices severely limits the usability of the reported test results as a proof for compliance to the FCC's interference mandate.
- The Progeny test environment is not representative of real-world operating conditions of various Part 15 devices and widely deployed Part 15 systems.
- Only stationary testing is done; vehicular testing is skipped altogether.
- The scope of Progeny testing was quite narrow. Comprehensive testing in a variety of environments such as rural and dense-urban and different conditions such as Line-of-Sight (LOS), co-location, and non-GPS-friendly (e.g., urban canyons) should have been carried out to properly evaluate the impact of WAPS interference.
- While the initial search for the test devices appears to be extensive, the finalized test devices happened to be more tolerant to interference due to their characteristics, masking the impact of WAPS interference on widely used commercial Part 15 devices that have characteristics quite different from those of the test devices.
- Single-device testing as opposed to more-realistic multi-device testing was performed. A multi-device environment increases the probability of interference due to the less amount of unoccupied spectrum bandwidth accessible to the Part 15 devices.
- Whenever the WAPS interference was detected during the Progeny tests, the audio quality of Part 15 devices was quite poor as indicated by the presence of a beep every second, but the Progeny report incorrectly considered such audio as good quality audio.
- The WAPS interference is capable of wiping out entire packets for Part 15 data devices, often rendering some devices inoperable. But, the Progeny report incorrectly assumes that there will not be any significant impact of WAPS interference on the data devices.

- The claimed location performance of the WAPS is not proven by any quantitative performance metrics and measurements.

- Detailed description of the WAPS network configuration and parameter settings that can yield the claimed location accuracy is absent.

- Location performance comparison of the WAPS and other non-WAPS systems is not described, raising questions about the viability of the WAPS as a commercial-grade location technology.

- Interference from Part 15 transmitters could potentially degrade the location performance of a WAPS receiver. However, the impact of Part 15 devices on the achievable WAPS performance is not evaluated at all.

- Critical quantitative performance metrics and associated measurements for the WAPS and Part 15 devices are not provided.

- The test results clearly show that the use of range as a performance metric for Part 15 data devices is unreliable.

- Poor choice of the test devices has caused improper classification of typical and atypical Part 15 device operations. Poor voice quality observed during so-called atypical operations would thus be observed during typical Part 15 device operations.

- The WAPS inherently relies upon a non-WAPS network such as a cellular or WiFi (Wireless Fidelity) network to convey the location of the device to the network. However, a real-world operational proof or even the feasibility study of such WAPS and cellular/WiFi interworking is missing. Considering significant challenges of such interworking for both the handset and the infrastructure, it is imperative that an extensive analysis of real-world interworking scenarios be published by Progeny.

In summary, the Progeny test and test report fails to prove that the WAPS would not cause unacceptable levels of interference to Part 15 devices and systems of devices.

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About the Author

Dr. Nishith Tripathi is a principal consultant at Award Solutions, a provider of technical consulting and specialized technical training for wireless communications. Dr. Tripathi's students include senior personnel from companies throughout the wireless industry as well as other wireless engineering instructors. Dr. Tripathi specializes in a variety of technologies, including IS-95, CDMA2000, 1xEV-DO, GSM, GPRS, EDGE, UMTS, HSDPA, HSUPA, HSPA+, WiMAX, and LTE. He received his doctorate in Electrical and Computer Engineering from Virginia Tech, and he has held several strategic positions in the wireless arena. As Senior Engineer for Nortel Networks, Dr. Tripathi gained direct hands-on experience analyzing and optimizing the performance of CDMA networks, in such areas as capacity, handoff and power control algorithms, supplemental channel management algorithms, and switch antenna diversity. As a Senior Systems Engineer and Product Manager for Huawei Technologies, he worked on the infrastructure design and optimization of CDMA2000, 1xEV-DO, and UMTS radio networks. Dr. Tripathi is the co-author of *Radio Resource Management* (2001) and *Cellular Communications: A Comprehensive and Practical Guide* (forthcoming) with Professor Reed. Dr. Tripathi has also contributed chapters to the following books: "Net Neutrality: Contributions to the Debate" (Edited by Jorge Perez Martinez, 2011) and "Neuro-Fuzzy and Fuzzy-Neural Applications in Telecommunications" (Edited by Peter Stavroulakis, Springer, April 2004). Dr. Tripathi's complete vita is attached.

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CONTENTS

Section 1 provides an overview of the comments made by SkyTel and others.

Section 2 gives an overview of standardized location solutions defined by Long-Term Evolution (LTE), which is expected to be the most dominant fourth-generation (4G) cellular technology in the U.S. and the world. *[See preceding Comments of SkyTel and this author for an initial discussion of the relevance of LTE in Progeny's materials.]*

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1. OVERVIEW OF COMMENTS ON THE PROGENY TEST REPORT

Note. The page numbers mentioned in this Reply Paper correspond to the page numbers in the pdf files of all the references.

Numerous critical issues about the Progeny test report [3] have been identified by SkyTel and others [1, 2, 4, 5, 6, 7, 8]. These issues can be broadly classified into these six major areas: (i) Area 1: Testing Approach, (ii) Area 2: Test Devices, (iii) Area 3: Impact of WAPS Interference on Part 15 Devices and Systems, (iv) Area 4: WAPS Design and Location Accuracy, (v) Area 5: Performance Metrics and Measurements, (vi) Area 6: Interworking of WAPS with Cellular and WiFi. The specific issues for each of these six areas are briefly discussed in Section 1.1 through Section 1.6 next.

1.1 Area 1: Testing Approach

Cooperative testing between the WAPS and existing Part 15 systems is not carried out. Progeny thus fails to meet the purpose of testing set forth by the FCC.

- SkyTel reiterated the FCC's mandate on Page 8 in [2][1]: "As the Commission noted, the purpose of the testing condition "is to insure that multilateration LMS licensees, when designing and constructing their systems, take into consideration a goal of minimizing interference to existing deployments or systems of Part 15 devices in their area, and to verify through cooperative testing that this goal has been served." [9]".

- SkyTel also noted on Page 8 in [2] that the testing was done by selecting a set of standalone Part 15 devices and that testing should have involved existing Part 15 systems to accurately quantify the impact of WAPS interference on the operation and performance of the Part 15 system and the impact of the Part 15 system on the accuracy of the location estimate of the M-LMS receiver.

- CellNet was one of the just two companies owning Part 15 systems that expressed concerns initially about Progeny's proposed system, and millions of automated meter reading (AMR) devices have been operating in the field (see Page 4 in [4]). It would have been easier for Progeny to do cooperative testing by working with CellNet.

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[1] The use of blue, for emphasis, is added herein and is not in original FCC text.

- Itron also commented that Progeny could have easily done cooperative testing with Itron, especially since 80 million Itron meter modules have been shipped nationwide (see Page 6 of [5]). Itron also states that Progeny tests disregard a large portion of Part 15 technologies (Page 3 of [5]).

- Kapsch mentioned on Page 2 in [7] that over 30 million vehicles are equipped with NM-LMS (Non Multilateration- Location and Monitoring Service). Cooperative testing with Kapsch would have been another possibility for Progeny.

- The Wireless Service Providers Association (WISPA) pointed to the existence of numerous fixed wireless broadband systems operating in the Part 15 spectrum on Page 2 in [8]. Instead of limited testing with just one wireless system, Canopy, more comprehensive testing with multiple representative wireless systems would have yielded more realistic results.

Inherent lack of co-channel interference (CCI) for most test devices severely limits the usability of the reported test results as a proof for compliance to the FCC's interference mandate.

- As noted by SkyTel on Page 8 in [2], the Part 15 test device selection method has led to many devices not operating on the same frequency spectrum bandwidth as the WAPS beacons. CCI truly tests the amount of potential WAPS interference. Since only few of the selected test devices could be forced to operate on the frequency spectrum used by the WAPS beacons, it was not surprising that the occurrence of the WAPS interference appeared to be less frequent. The true impact of WAPS interference cannot be estimated based on the Progeny test results. See [2] and [3] for more details on the operating frequency ranges of the test devices and the WAPS beacons.

- Itron also highlighted the virtual absence of the CCI during the inadequate Progeny tests as a result of selected test devices (Page 11 of [5]).

The Progeny test environment is not representative of real-world operating conditions of various Part 15 devices and widely deployed Part 15 systems.

- CellNet indicates on Page 4 of [4] that the typical operating environment of the AMR device is not reflected in the Progeny test cases. For example, the AMR device operates outdoor, while Progeny focuses on indoor testing. As another example, the break-case of an AMR device could occur in the LOS case within 50 m of the WAPS beacon, which is different from the Progeny-assumed break-case.

- Itron found that Progeny made incorrect assumptions about how and where Part 15 devices operate (Page 5 of [5]). Itron identified a variety of AMR devices such as pole-mounted fixed devices with more than a two-mile radius, handheld devices, drive-by mobile devices, and consumer engagement devices (Page 8 of [5]). Itron mentioned that testing of commercial or industrial devices ignored the true deployment and system operations of the Part 15 devices (Page 12 of [5]).

- The WISPA states that Progeny test assumptions deviate significantly from the real-world conditions (Page 4 of [8]). While the Canopy system used by Progeny uses BPSK (Binary Phase Shift Keying) that is more robust to interference, testing with other less robust modulation methods was not carried out for BWA systems (Page 6, [8]). A typical broadband wireless access (BWA) does not use frequency hopping or automatic frequency agility (Page 6, [8]). Furthermore, manual or auto switching to another channel is not an option for most outdoor BWA systems because of the limited number of 900 MHz channels (Page 6, [8]).

Only stationary testing is done; vehicular testing is skipped altogether. Since a Progeny receiver as well as some Part 15 devices could be mobile, vehicular testing should have been carried out.

- SkyTel observed on page 9 of [2] the absence of vehicular testing, further restricting the applicability of the Progeny test results.
- Itron also observed the lack of testing related to the vehicular location service of the Progeny system (Page 3 of [5)).

The scope of Progeny testing was quite narrow. Comprehensive testing in a variety of environments such as rural and dense-urban and different conditions such as Line-of-Sight (LOS), co-location, and non-GPS-friendly should have been carried out to properly evaluate the impact of WAPS interference.

- Itron pointed to the failure by Progeny to conduct Line of Sight, co-location, and height testing (e.g., devices on pole tops or towers) on Pages 12 and 13 of [5].
- The WISPA mentioned that Progeny did not test in rural areas where typical WISPs (Wireless Internet Service Providers) operate (Page 7 of [8]).

1.2 Area 2: Test Devices

While the initial search for the test devices appears to be extensive, the finalized test devices happened to be more tolerant to interference due to their characteristics, masking the impact of WAPS interference on widely used commercial Part 15 devices that have characteristics quite different from those of the test devices.

- CellNet mentions on Page 5 of [4] that machine-to-machine (M2M) communications is less tolerant of interference than the communications of consumer devices.

- Itron has reported almost a dozen generations of devices in the field with varying characteristics of power, modulation, and channel usage (Pages 11 and 12 in [5]). Progeny has tested just one AMR device. While Progeny focused on 2005 and newer devices, legacy devices often have a lifespan of twenty years (Page 13 in [5]).

Single-device testing as opposed to more-realistic multi-device testing was performed. A multi-device environment increases the probability of interference due to the less amount of unoccupied spectrum bandwidth accessible to the Part 15 devices.

- SkyTel noted on Pages 8 and 9 in [2] that it was much easier for a test device to find an unoccupied channel due to a single active Part 15 device, avoiding the Part 15 interference and WAPS interference. The likelihood of WAPS interference increases significantly depending upon the number of Part 15 devices, the operational frequency ranges of Part 15 devices, and the existence of Part 15 systems.

1.3 Area 3: Impact of WAPS Interference on Part 15 Devices and Systems

Whenever the WAPS interference was detected during the Progeny tests, the audio quality of Part 15 devices was quite poor as indicated by the presence of a beep every second, but the Progeny report incorrectly considered such audio as good quality audio.

- A beep every single second during the conversation would be annoying to most people as noted by SkyTel in [2]. Traditionally, acceptable speech quality corresponds to 1% to 3% error rate, meaning 3 speech frames (each with a 20 ms time interval) and up to 60 ms duration containing errors within a 2000 ms interval would be tolerable. Progeny specified on Page 10 of [3] that each transmitter uses *up to* two 100 ms slots during one second interval. Even if only one 100 ms slot is used per second for a transmitter, there would be a total of 200 ms duration of WAPS beacons within a 2-second interval. The frame error rate could be as high as 10% due to 10 frames being in error (caused by WAPS interference lasting for 200 ms) out of 100 frames (equivalent to 100 frames * 20 ms per frame= 2 second)[2]. If a WAPS transmitter uses two 100 ms slots during one second interval, the frame error rate could be 20%.

- Itron revealed that operations of several legacy AMR devices are disproportionately centered in the middle of the 902-928 MHz band that is near the center M-LMS channel and that AMR fixed devices or WISP transmitters, out of necessity, will be collated with Progeny devices on utility poles or towers (Page 8 of [5]). Furthermore, many Part 15 devices send reports to the reader device every X seconds (e.g., X= 4, 7, or so on) using "fire+forget" model. Such reporting schedule could exactly match the WAPS beacon's 100 ms transmission slots and many devices will not change the reporting schedule (Page 15 of [6]). There could be significant WAPS interference in all of these situations. Itron also found that the Progeny system would cause overload to a device located within 0.25 km of a Progeny beacon (Page 14 of [5]).

- Kapsch states that the 100 ms long WAPS beacon transmission could cause entire loss of service to the devices using its NM-LMS system and that many sub-channels used by its NM-LMS system would become unusable due to the WAPS interference (Page 5 of [7]).

The WAPS interference is capable of wiping out entire packets for Part 15 data devices, often rendering some devices inoperable. But, the Progeny report incorrectly assumes that there will not be any significant impact of WAPS interference on the data devices.

- SkyTel mentioned on Page 5 of [2] that the continuous transmission of beacons for 100 ms is problematic for (both speech and) data whenever strong WASP signals become CCI for the Part 15 devices. It is well-known that the physical layer cannot overcome a long burst of errors. Since the beacon is present for a long time, the probability of entire (speech and) data packets being lost is very high.

- CellNet also states on Page 6 in [4] that the entire data packets could be lost during the beacon transmissions, requiring retransmissions and degrading the performance of the data devices. Some devices that have been operating in the field for many years could very well become non-operational due to the use of a single frequency that can coincide with the Progeny beacon frequencies (see Page 6 of [4]).

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[2] We would like to correct the typo on Page 10 of our report [2], where the frame error rate of 5% is mentioned instead of 10%.

1.4 Area 4: WAPS Design and Location Accuracy

The claimed location performance of the WAPS is not proven by any quantitative performance metrics and measurements.

- SkyTel mentioned on Page 4 of [2] that relevant measurements such as received signal strengths and beacon (or pilot) (E_c/I_0) for M-LMS should have been specified. In the absence of quantitative performance metrics and measurements obtained during comprehensive tests, there is no way of validating or confirming the claimed location accuracy of the Progeny system.

Detailed description of the WAPS network configuration and parameter settings that can yield the claimed location accuracy is absent.

- SkyTel stated on Page 4 of [2] that the (WAPS) deployment configuration has a direct impact on the accuracy of the location estimates and the interference caused to Part 15 receivers. The test results should include the achieved location accuracy due to the tradeoff between the density of the beacon transmitters and the interference caused to Part 15 devices. Additionally, the WAPS is intended to provide superior performance where GPS-based solutions are insufficient (e.g., in dense-urban areas). However, adequate testing in such areas is not really done.

Location performance comparison of the WAPS and other non-WAPS systems is not described, raising questions about the viability of the WAPS as a commercial-grade location technology.

- SkyTel identified absence of a comprehensive performance comparison among the Progeny WAPS and the existing location systems on Page 6 of [2]. Since the WAPS design parameters such as a very low data rate of 50 bps and a 100 ms timeslot carrying data every second appear to be inadequate (in the absence of any supporting proof of performance), such performance comparison becomes quite important [2].

Interference from Part 15 transmitters could potentially degrade the location performance of a WAPS receiver. However, the impact of Part 15 devices on the achievable WAPS performance is not evaluated at all.

- SkyTel mentioned on Page 5 of [2] that impact of the Part 15 transmitters on the accuracy of the location estimate devices on the WAPS performance is not evaluated.

1.5 Area 5: Performance Metrics and Measurements

Critical quantitative performance metrics and associated measurements for the WAPS and Part 15 devices are not provided.

- ➢ A mere mention of the achievable location accuracy or qualitative description of the impact of WAPS interference on Part 15 devices is not adequate. As reported in SkyTel on Page 9 of [2], quantitative performance metrics and relevant measurements should be recorded and provided as well. Example measurements include received signal strength, signal to interference ratio (SIR), and pilot (Ec/I0). Voice-specific and data-centric performance metrics are frame or block error rate and throughput.

The test results clearly show that the use of range as a performance metric for Part 15 data devices is unreliable.

- ➢ SkyTel observed on Page 11 of [2] that range as a performance metric is not useful as indicated by an increased range when the WAPS network is activated.
- ➢ Itron also observed that the measurements are frequently better for the (WAPS) system "off" case than the (WAPS) system "on" case (Page 10 of [6]).

Poor choice of the test devices has caused improper classification of typical and atypical Part 15 device operations. Poor voice quality observed during so-called atypical operations would thus be observed during typical Part 15 device operations.

- ✓ SkyTel noted on Page 10 of [2] that the situation where Part 15 devices always operated on the same frequency as a WAPS beacon is considered atypical by Progeny but could very well be typical for numerous devices. Even when a Part 15 device supports multiple frequency channels, the probability of an unoccupied channel becoming available reduces and the probability of WAPS interference increases as the number of Part 15 devices increases in a given geographic area.

1.6 Area 6: Interworking of WAPS with Cellular and WiFi

The WAPS inherently relies upon a non-WAPS network such as a cellular or WiFi (Wireless Fidelity) network to convey the location of the device to the network. However, **a real-world operational proof or even the feasibility study of such WAPS and cellular/WiFi interworking is missing**. Considering significant challenges of such interworking for both the handset and the infrastructure, it is imperative that an extensive analysis of real-world interworking scenarios be published by Progeny.

- ✓ As mentioned by SkyTel on Page 6 of [2], the WAPS network inherently relies upon a non-WAPS network such as a cellular or WiFi network for the M-LMS receiver to convey its location and height to the network. The M-LMS device requires special hardware for Radio Frequency (RF) measurements and software for Secured User Plane (SUPL) and for interworking between M-LMS and cellular or WiFi.

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2. LOCATION SERVICES IN LTE

[As noted above: see preceding Comments of SkyTel and this author for an initial discussion of the relevance of LTE in Progeny's materials.]

The Progeny WAPS does not have an uplink from the Progeny device to the WAPS, because the WAPS is a broadcast-only network (Page 6 of [3]). Hence, the Progeny location service relies upon another access network such as cellular or WiFi and Secure User Plane (SUPL) protocol (Page 6 of [3]). LTE is emerging as a dominant 4G cellular technology. LTE has its own fully-standardized location solutions including a control plane or signaling solution and a user plane solution (i.e., SUPL). LTE supports a variety of positioning techniques including a multilateration technique[3]. Furthermore, as we will see later in this section, the LTE location solution is quite flexible and has several means to enhance location accuracy. The Progeny WAPS, in contrast, has very limited degrees of freedom to adapt the WAPS to meet the target location accuracy. An introduction to the LTE's location services (LCS) architecture is provided below including the support for E911 calls. The positioning techniques supported by LTE are then summarized. Finally, location solutions of LTE and Progeny WAPS are compared.

LTE is introduced in Release 8 of the Universal Mobile Telecommunication System (UMTS) by the 3GPP (Third Generation Partnership Project). Verizon and AT&T have been deploying LTE in the U.S. LTE is expected to be dominant cellular technology in the licensed spectrum with many initial deployments occurring at 700 MHz. Several frequency bands including traditional cellular band (around 850 MHz), PCS (Personal Communication Service) band (around 1900 MHz), and AWS (Advanced Wireless Service) (around 1.7 GHz and 2.1 GHz) are supported by the LTE standard, and, LTE deployments using these frequency bands would gradually emerge. LTE exploits Orthogonal Frequency Division Multiple Access (OFDMA), advanced antenna techniques such as Multiple Input Multiple Output (MIMO), high-order modulation such as 64-QAM (Quadrature Amplitude Modulation), and wide bandwidth (e.g., 10 MHz downlink and 10 MHz uplink in a typical deployment) to achieve very high data rates on the air interface. When full potential of Release 8 is realized, the peak data rates of 300 Mbps in the downlink and 75 Mbps in the uplink are achievable. LTE-Advanced is introduced in Release 10 by the 3GPP with the peak achievable data rates in excess of 1 Gbps.

Release 9 defines location services (LCS), where a variety of location based services (LBS) such as Emergency 911 or E911 calls and value-added services (e.g., directions to a restaurant and a list of restaurant in the vicinity of the mobile device) can be offered to the LTE subscribers. The main benefits of the LTE LCS are as follows.

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[3] It is up to the cellular service provider the specific nature of the LCS solution and the specific technique(s) chosen for positioning. Furthermore, different LTE mobile devices would have different LCS capabilities. Existence of a Global Positioning System (GPS) receiver in the mobile device is becoming common today (including LTE).

- ✓ LTE LCS is a fully-standardized solution that gives the service operators flexibility while choosing the vendors for various network elements and mobile devices.
- ✓ LTE LCS enables economies-of-scale due to the expected massive cellular adoption of LTE.
- ✓ LTE LCS facilitates interoperability testing due to the standardized nature of the solution.
- ✓ The LTE service provider can offer LBS as part of its existing IMS (IP Multimedia System) network, which enables rapid introduction of new services cost-effectively.
- ✓ The LBS can be assigned a suitable class of Quality of Service (QoS) as the LBS are operator-aware and operator-controlled services. LTE supports nine different QoS classes, and, a given application is assigned an appropriate QoS class.

A brief overview of LCS in LTE can be found in [12]. See [13] and [14] for additional details of the LTE LCS architecture and LTE positioning methods. Estimation of location accuracy of various LTE positioning methods can be found in [15]; the overall E911-mandated accuracy targets can be met by combining multiple positioning methods.

Figure 1 below illustrates the major elements of the LCS architecture [10]. We will (1) first see how User Equipment's (UE's) location can be found using the LCS entities for a generic location based service, (2) then briefly discuss how an E911 call from the UE is handled.

(1) Assume that an external LCS client such as a value-added service is trying to find the UE's location[4].

- ➢ Such client makes a location request to the Gateway Mobile Location Center (GMLC).
- ➢ The GMLC authorizes such client.
- ➢ The GMLC acts as a location server and relies upon the Mobility Management Entity (MME) to find the UE's location.
- ➢ The MME has a logical signaling connection with the UE via the E-UTRAN[5] so that relevant signaling messages (e.g., permission by the subscriber for finding the location) can be exchanged between the UE and the MME.

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[4] The location approach described here is based on signaling. Another location approach uses the user plane and is referred to as Secured User Plane (SUPL).

[5] The eNodeB is a cellular base station and communicates with the UE using the air interface of LTE. Multiple eNodeBs or eNBs constitute the LTE's radio network called Evolved- Universal Terrestrial Radio Access Network (E-UTRAN).

- The MME chooses a specific Evolved- Serving Mobile Location Center (E-SMLC) for the UE.
- The E-SMLC is in charge of deciding one or more specific UE positioning methods for the UE. We have briefly summarized the positioning methods of LTE below.
- The E-SMLC works with the eNodeB and the UE to determine the UE location (e.g., lat and long and potentially height).
- The E-SMLC provides the UE location to the MME, which in turn conveys the UE location to the GMLC.
- The external LCS client now learns about the UE location from the GMLC.

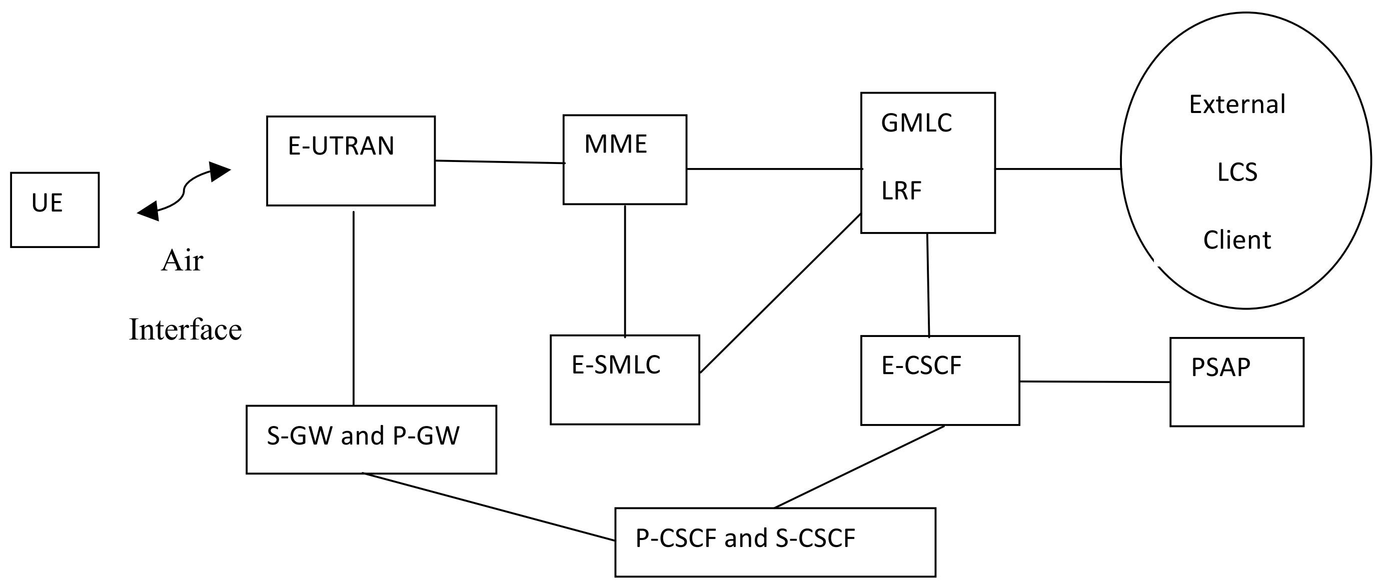

Figure 1. LCS Architecture and Support for E911 in LTE (simplified from [10])

(2) Let's see how UE's E911 call is routed through the LTE network:

- LTE supports E911 using the IMS that includes entities such as the Proxy- Call Session Control Function (P-CSCF) and Serving- Call Session Control Function (S-CSCF).
- The UE's E911 call uses Session Initiation Protocol (SIP) messages that pass through the eNodeB, the Serving Gateway (S-GW), and the Packet Data Network Gateway (P-GW) and reach the P-CSCF.
- The P-CSCF consults the S-CSCF that determines the registration period for the session.
- The P-CSCF forwards the emergency session to the Emergency- Call Session Control Function (E-CSCF).

- The E-CSCF communicates with the Location Retrieval Function (LRF) to find the correct destination address of a Public Safety Answering Point or PSAP so that the UE's E911 call can be routed to the proper PSAP.
- Furthermore, the LRF is responsible to retrieve the location of the UE by working with the GMLC. The GMLC relies upon the MME to find the UE location.
- The MME contacts an E-SMLC, which interacts with the eNodeB and the UE to find the UE location.
- The UE location is now conveyed to the MME by the E-SMLC.
- The UE location finally reaches the E-CSCF via the MME, the GMLC, and the LRF.
- The E-CSCF can next work with the PSAP to support the E911 call.

Now that we know how LTE supports a location service, let's discuss the main UE positioning techniques supported by LTE. These techniques include Enhanced Cell Identity (E-CID), Assisted- Global Navigation Satellite System (A-GNSS), and Observed Time Difference of Arrival (OTDOA) [11]. The E-SMLC utilizes one or more of these techniques to determine the UE location (2-dimensional or 3-dimensional).

- **E-CID**. Since the UE in the connected mode has a dedicated a radio connection with the E-UTRAN, the E-UTRAN knows about the cell where the UE is located. The eNodeB can then use measurements of the round trip time (RTT) to determine the distance between the eNodeB and the cell. The angle-of-arrival (AoA) can finally be used to find the UE location, because the distance and the angle together are adequate to locate the UE.
- **A-GNSS**. A-GNSS is a generic term where satellite signals are used by the UE to make measurements. In the U.S., Assisted- Global Positioning System (A-GPS) can be expected be popular. The UE's search for satellites is facilitated by conveying the information about the satellites to the UE.
- **OTDOA.** This is a traditional multilateration technique where the E-UTRAN signals are processed by the UE to provide a report to the E-SMLC. Each E-UTRAN cell transmits cell-specific reference signals. In addition, special positioning reference signals (PRS) have been defined in Release 9 to support the UE positioning. The UE can now make measurements of the reference signals and provide a measurement report to the E-SMLC. The E-SMLC determines the actual location of the UE based on the UE measurements (and potentially the eNodeB measurements as well).

In summary, LTE supports a variety of UE positioning techniques in a standardized fashion. Multiple techniques can be combined for a more refined location estimate.

Here are the main differences between the LTE location solution and the Progeny location solution.

- ✓ Compared to the LTE positioning techniques, the Progeny WAPS appears to be quite inflexible.
- ✓ A fixed time slot of 100 ms for the beacon transmission and a low data rate of 50 kbps can impose significant constraints on the achievable location accuracy of the Progeny system.
- ✓ LTE provides a standardized location solution, whereas the Progeny solution requires a proprietary receiver design.
- ✓ The Progeny design needs to overcome the complexity and interoperability challenges.
- ✓ LTE can control the QoS for the location services, while it would be quite challenging for the Progeny solution to get LTE-type QoS control.

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[2] Nishith D. Tripathi (for SkyTel), "Review of the "WAPS" and "Part 15 Test Report"," Attachment to [1], March 15, 2012.

[3] Progeny LMS, LLC, "Demonstration of Compliance with Section 90.353(d) of the Commission's Rules," WT Docket No. 11-49, January 27, 2012.

[4] Charles Pellissier, "COMMENTS OF CELLNET TECHNOLOGY, INC," In the Matter of "Request of Progeny LMS, LLC for Waiver of Certain Multilateration Location and Monitoring Service Rules," WT Docket No. 11-49, March 15, 2012.

[5] Laura Stefani and Henry Goldberg, "COMMENTS OF ITRON, INC. ON PROGENY TEST REPORT," In the Matter of "Progeny LMS, LLC- Petition for Waiver of the Rules And Request for Expedited Treatment," WT Docket No. 11-49, March 15, 2012.

[6] RKF Engineering Solutions (for Itron), "Analysis of Progeny Part 15 Test Report," March 15, 2012.

[7] Alastair Malarky and George Y. Wheeler, "COMMENTS OF KAPSCH TRAFFICCOM IVHS INC," In the Matter of "Request by Progeny LMS, LLC for Waiver of Certain Multilateration Location and Monitoring Service Rules, WT Docket No. 11-49, March 15, 2012.

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[9] LMS MO&O, 12 FCC Rcd at 13968 ¶ 69.

[10] 3GPP, TS 23.271, "Functional stage 2 description of Location Services (LCS)," Release 10, Version 10.0.0, June 2010.

[11] 3GPP TS 36.305, "Stage 2 functional specification of User Equipment (UE) positioning in E-UTRAN," Release 9, Version 9.4.0, September 2010.

[12] Nishith Tripathi, "Overview of LCS in LTE," a video tutorial at http://lteuniversity.com/get_trained/video_tutorials/m/videotutorials/11530.aspx.

[13] MultiService Forum, "MSF Whitepaper on Location Services in LTE Networks," April 2010, http://www.msforum.org/techinfo/reports/MSF-TR-SERVICES-005-FINAL.pdf.

[14] Ericsson, "Positioning with LTE," September 2011, http://www.ericsson.com/res/docs/whitepapers/WP-LTE-positioning.pdf.

[15] Karri Ranta-aho (Nokia Siemens Networks), "Performance of 3GPP Rel-9 LTE positioning methods," 2nd Invitational Workshop on Opportunistic RF Localization for Next Generation Wireless Devices, June 13 - 14, 2010.

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AUTHOR VITA

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AREAS OF EXPERTISE

LTE (E-UTRAN and EPC), LTE-Advanced, WiMAX, 1xEV-DO (Rev. 0 and Rev. A), UMTS R99, HSDPA, HSUPA, HSPA+, CDMA2000 1xRTT, IS-95, CDMA, OFDM, OFDMA, Advanced Antenna Technologies, IP-related Technologies, IMS

PUBLICATIONS

- Author of an upcoming **book** (with Jeffrey H. Reed), "Cellular Communications: A Comprehensive and Practical Guide," ***Accepted for Publication by IEEE/Wiley***, 2012. (**Book Contents**: Introduction to Cellular Communications, Elements of a Digital Communication System, Radio Propagation, IP Fundamentals, GSM, GPRS, EDGE, IS-95, CDMA2000 1xRTT, R99 UMTS/WCDMA, 1xEV-DO Rev. 0, HSDPA, 1xEV-DO Rev. A, HSUPA, HSPA+, IMS, Emerging 4G Technologies)
- Author of a **book** (with Jeffrey H. Reed and Hugh F. VanLandingham), "Radio Resource Management in Cellular Systems," Kluwer Academic Publishers, 2001.
- Contributor (With Jeffrey H. Reed) to the article, "Technical Challenges in Applying Network Neutrality Regulations to Wireless Systems," in the book titled "Net Neutrality: Contributions to the Debate," Edited by Jorge Perez Martinez, 2011.
- Author of one chapter in the book, "Neuro-Fuzzy and Fuzzy-Neural Applications in Telecommunications," Editor- Peter Stavroulakis, Springer, April 2004.

EXPERIENCE

AWARD SOLUTIONS *March '04 to Present*

Principal Consultant

- Successfully launched a new program to ensure and develop SME (Subject Matter Expert) expertise in the areas of LTE RAN and Ethernet-based Backhaul. Developed processes and plans to facilitate SME certification. Devised expertise development plans, on-line tests, and defense tests. Directed the oral defense meetings for the final stage of SME certification.
- Managed and led SMEs for following course development projects: LTE Bootcamp-Phase II (**Topics**: End-to-end Data Sessions in LTE-EPC, PCC: QoS and Charging Architecture for LTE, Voice over LTE (VoLTE) using IMS, Voice services using CSFB and SRVCC, LTE and eHRPD Interworking, LTE and GSM/UMTS interworking, and LTE-Advanced), and LTE Radio Network Planning and Design.
- Mentored SMEs to prepare them to teach technologies such as LTE, WiMAX, OFDM, and Advanced Antennas.
- Developed courses on LTE-Advanced and TD-LTE.
- Developed two sessions, TD-LTE and Self Organizing Network (SON), as part of LTE Bootcamp- Phase II for an infrastructure vendor.
- Enhanced the LTE Radio Network Planning and Design course to reflect configurations of commercial deployments using LTE log-files and to adhere to customer-specific RF design guidelines.
- Continued to teach a variety of LTE and HSPA+ courses (e.g., VoIP, IMS, and IPv6 for LTE and HSPA+ Signaling) at new and existing clients.
- Delivered several web-based sessions of LTE Bootcamp- Phase II.

Lead SME

- Taught *first-time offerings* of courses at various clients to acquire new training business.

- Managed and guided SMEs for timely and quality-controlled completion of following course development projects: LTE/1xEV-DO Interworking, EPC Overview, HSPA+ Overview, Fundamentals of RF Engineering, IP Convergence Overview, and Advanced Antenna Techniques.
- Devised and implemented strategies to maximize the quality of project deliverables and to accelerate the completion of the deliverables.

SME- Course Development

- Developed an in-depth LTE Bootcamp Series for an infrastructure vendor (**<u>Topics</u>**: EPS Network Architecture, OFDMA/SC-FDMA, Radio Channels, System Acquisition & Call Setup, DL & UL Traffic Operations, Handover, and Antenna Techniques).
- Developed numerous instructor-led and web-based training courses by working in a team environment (**<u>Examples</u>**: Interworking of LTE with 1xEV-DO & 1xRTT, LTE Air Interface, WiMAX Essentials, WiMAX Network Planning, UMB, 1xEV-DO, HSUPA, Multiple Antenna Techniques, and IP Convergence).
- **<u>Example Course Contents</u>**: Network architecture, air interface features, DL & UL data transmission, call setup, handover/handoff, resource management, and interworking.
- Designed outlines for several new courses.

Senior Consultant- Training

- Taught *in-person* and *web-based* (via WebEx and LiveMeeting) courses at major chip-set manufacturers, infrastructure & device vendors, service operators, and test-tool vendors.
- Delivered an in-depth LTE bootcamp multiple times for a major LTE infrastructure vendor.
- **<u>Area Expertise</u>**: LTE Radio Network Planning & Design (including Certification), Interworking of LTE with (1xEV-DO, 1xRTT, UMTS, and GERAN), LTE Protocols & Signaling, LTE Air Interface, WiMAX Networks and Signaling, 1xEV-DO Optimization, 1xEV-DO Rev. 0 and Rev. A, IP Fundamentals, HSDPA/HSUPA/HSPA+, UMTS R4/R5 Core Networks, UMTS Network Planning and Design
- Strived to make the training experience full of *relevant* knowledge and to maximize the value of training to students.

VIRGINIA TECH *January'10 to Present*
Adjunct Professor

- Co-taught the cellular communications class.
- Developed and presented the lecture material.
- Designed and graded quizzes.

HUAWEI TECHNOLOGIES *October '01 to March '04*
Product Manager and Senior Systems Engineer

- Worked with engineers to resolve numerous **field trial issues** for **CDMA2000** systems.
- Defined test procedures for various features to evaluate performance of the CDMA2000 product.
- Designed advanced RL MAC and Power Control algorithms for a 1xEV-DO System.
- Designed various high-performance radio resource management (RRM) algorithms for the **CDMA2000** base station and base station controller. Major designed features include adaptive forward link and reverse link call admission control algorithms, dynamic F-SCH rate and burst duration assignment algorithms, R-SCH rate assignment algorithm, F-SCH burst extension and termination mechanisms, schedulers, forward link and reverse link overload detection and control algorithms, SCH soft handoff algorithm, F-SCH power control parameter assignment mechanism, adaptive radio configuration assignment algorithm, load balancing algorithm, and cell-breathing algorithm.
- Worked on the design of an RRM simulator to evaluate the performance of call admission control, load control, and scheduling algorithms for a **CDMA2000** system.

- Designed system level and network level simulators to evaluate the capacity gain of the smart antenna-based **UMTS** systems employing multiple beams.
- Reviewed **UMTS** RRM design and proposed enhancements related to call admission control, cell breathing, load balancing, soft capacity control, potential user control, and AMR control.
- Educated engineers through presentations to facilitate development of the **1xEV-DO** product.
- Led a team of engineers to define a comprehensive **simulation tool-set** consisting of link level simulator, system level simulator, and network level simulator to evaluate performance of CDMA systems including **IS-95**, **IS-2000**, **1xEV-DO**, **1xEV-DV**, and **UMTS**.
- Managed a group of engineers, prepared project plans, and established efficient processes to meet the requirements of the **CDMA2000** BSC product line.

NORTEL NETWORKS *September '97 to September '01*

Senior Engineer

<u>Radio Resource Management, July '99 to Sept. '01</u>

- Developed a comprehensive RRM simulator that models data traffic and major features of the MAC layer and physical layer. Analyzed various aspects of the RRM for several test cases. The performance results such as capacity and throughput were used in educating the service providers on the RRM for IS-2000 systems.
- Proposed a generic call admission control algorithm and filed a patent with the U.S. Patent Office.

<u>Management of Supplemental Channels, June '00 to Sept. '01</u>

- Designed and analyzed supplemental channel management for enhanced data performance and filed a patent with the U.S. Patent Office.
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<u>Data Traffic Modeling, Jan. '99 to Sept. '01</u>

- Prepared a common framework for data traffic models for analysis of systems carrying data (e.g., 1xRTT and UMTS). Types of analysis include RF capacity, end-to-end performance, and provisioning. The data models for telnet, WWW, ftp, e-mail, FAX, and WAP services are considered.

<u>Multi-Carrier Traffic Allocation, June '99 to Sept. '01</u>

- Provided MCTA capacity improvements (compared to non-MCTA systems) that proved to be identical to the ones observed during the field-testing. Developed a method to estimate the MCTA capacity using the field data. This method was used in estimating MCTA capacity gains by RF engineering teams.

<u>SmartRate and Related Vocoder Designs (e.g., SMV), June '99 to Sept. '01</u>

- Provided estimates of SmartRate capacity improvements that were found to be close to the observed capacity gains in the field tests.

<u>CDMA Based Fixed Wireless Access Systems, Sept. '97 to Dec. '98</u>

- **Capacity Estimates**. Determined the system capacity for a variety of configurations using an IS-95 based simulator. These configurations include different rates such as 9.6 kbps and 13 kbps, different deployment scenarios such as 2-tier embedded sector and border sector, and different diversity techniques such as switch antenna diversity and phase sweeping transmit diversity. These capacity estimates were used for various project bids. The simulator utilizes propagation channel models extracted from the actual field measurements.
- **Handoff and Power Control Algorithms**. Analyzed existing handoff and power control mechanisms for fixed wireless systems and proposed new approaches.
- **Bridge between the Simulator and a Deployed System**. Developed a procedure to estimate the loading level for the simulator so that the capacity estimate from the simulator is close to the achieved capacity in real systems.
- **Switch Antenna Diversity Schemes**. Proposed three algorithms to exploit mobile switch antenna diversity. These schemes provide a low-cost solution that significantly enhances RF capacity.

  Combined Overhead Power and Handoff Management. Proposed a method of combined management of overhead channel power and handoff to improve capacity.

Educator

- Made presentations on topics such as data modeling, fixed wireless systems, and AI tools.
- Taught "Introduction to Wireless" class at Nortel.
- Prepared tutorials on the standards such as 1xRTT, 1xEV-DO, and UMTS.

VIRGINIA TECH *January '93 to August '97*

Research/Teaching Assistant, Mobile & Portable Radio Research Group (MPRG), Electrical Engineering

- Developed adaptive intelligent handoff algorithms to preserve and enhance the capacity and the Quality of Service of cellular systems.
- Helped *develop* and *teach* a new wireless communications course **(DSP Implementation of Communication Systems**) as part of an **NSF** sponsored curriculum innovations program. Implemented different subsystems of a communication system (e.g., a digital transmitter, a carrier recovery system, a code synchronizer, and a symbol timing recovery system) using the **Texas Instruments** TMS320C30 DSP development system.
- Refined the class material for undergraduate and graduate signal processing classes.
- Investigated different aspects involved in dual-mode adaptive reconfigurable receivers as part of a project sponsored by **Texas Instruments**.

PATENTS/DRAFTS (AUTHOR/CO-AUTHOR)

- Enhanced Power Control Algorithms for CDMA-Based Fixed Wireless Systems, Patent Number 6,587,442, Filed Date: October 28, 1999.
- Method and apparatus for managing a CDMA supplemental channel, Patent Number 6,862,268, Filed Date: December 29, 2000.
- Dynamic Power Partitioning Based Radio Resource Management Algorithm, Patent Disclosure No.: 11942RR, Filed Date: August 23, 2000.
- Switch Antenna Diversity Techniques at the Terminal to Enhance Capacity of CDMA Systems, Patent Disclosure No. RR2544, Filed Date: June 19, 1998.
- Adaptive Radio Configuration Assignment for a CDMA System, October 2003.
- Multi-carrier Load Balancing for Mixed Voice and Data Services, October 2003.
- Methodology for Hierarchical and Selective Overload Control on Forward and Reverse Links in a CDMA System, October 2003.
- A New Predictive Multi-user Scheduling Scheme for CDMA Systems, November 2003.
- A New Method for Solving ACK Compression Problem by Generating TCK ACKs based on RLP ACKs on the Reverse Link, October 2003.

ACTIVITIES

Member of **IEEE**. Reviewed research papers for the *IEEE Transactions on Vehicular Technology*, *IEE Electronics Letters* and the *IEEE Control Systems Magazine*.

EDUCATION

VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY **Blacksburg, VA**

Ph.D., Wireless Communications, August 1997, Overall GPA: 3.8/4.0

Dissertation: Generic adaptive handoff algorithms using fuzzy logic and neural networks

M.S., Electrical Engineering, November 1994, Overall GPA: 3.8/4.0

GUJARAT UNIVERSITY **Ahmedabad, India**

B.S., Electrical Engineering, September 1992

Graduated among the top 2% of the class.